REMARKS

Claims 1-4, 6-22, 28-38, and 40-47 are pending. Claims 12-14, 17-19, and 22 are rejected under 35 U.S.C. § 102(b). Claims 1-4, 6-11, 14-16, 20-21, 28-38, and 40-47 are rejected under 35 U.S.C. § 103(a).

Examiner states that the rejection of independent claims 1, 8, 28, 32, 37, 42, and 45 stands or falls with that of claims 12 and 18. Although applicants do not necessarily agree, applicants' new arguments will be directed to Examiner's new rejection of independent claims 12 and 18. Regarding the "path profile" of claims 12 and 18, Examiner states limitations from the specification are not read into the claims. *In re Van Geuns*, 988 F.2d 1181, 26 USPQ2d 1057 (Fed. Cir.1993). The relevant facts of *In re Van Geuns* are these. Van Geuns provoked an interference by copying claims 1-4 and 9-10 from U.S. Pat. No. 4,587,504 issued to Brown et al. into U.S. Application No. 657,636 as new claims 42-47. Both the patent and the application were directed to Nuclear Magnetic Resonance (NMR) and Magnetic Resonance Imaging (MRI). The Board of Patent Appeals held that independent claim 42 was unpatentable under section 103 because of Japanese published application 52-90293 (the Japanese reference) taken alone or in view of German published patent specification 26 46 467 (the German reference). Van Geuns appealed the September 25, 1990 decision of the Board to the Court of Appeals for the Federal Circuit.

The issue before the Court was whether the recitation of a "uniform magnetic field" in Van Geuns' claim 42 rendered it patentable. The Board found that the Japanese reference disclosed a magnetic assembly with a substantially uniform magnetic field varying no more than 10 percent. Van Geuns argued that claim 42 must be interpreted in light of the specification. In particular, Van Geuns argued that the Japanese reference did not teach the level of magnetic field uniformity required for NMR imaging. However, claim 42 was not expressly limited to NMR or MRI apparatus. Van Geuns did not argue that the Japanese reference did not disclose a "uniform magnetic field." Rather, Van Geuns argued that the Japanese reference did not disclose a sufficiently uniform magnetic field. Therefore, Van Geuns' argument was based on a requisite

degree of uniformity of the magnetic field of claim 42 rather than whether or not a "uniform magnetic field" was disclosed by the Japanese reference. Thus, Van Geuns could not persuasively argue that the magnetic field of the Japanese reference was not sufficiently uniform to fall within the limitation of claim 42.

However, the Board did not rest its decision as to the unpatentability of claim 42 entirely on the absence of an NMR limitation in the claim. The Board further relied on expert testimony of Dr. Overweg, an expert for Brown et al., to determine the knowledge of one of ordinary skill in the art. The Court held "even if the claims were limited to NMR or MRI apparatus, in light of what the Japanese reference teaches one of ordinary skill in the NMR or MRI art, the board did not err in concluding that claim 42 would have been obvious." *In re Van Geuns*, 988 F.2d 1181, 1185 (Fed. Cir.1993). Thus, the Court's decision was not based on Van Geuns' inability to read NMR or MRI limitations into claim 42. The Court decided that even if NMR or MRI limitations were present, in claim 42 would have been obvious. Applicants respectfully submit, therefore, that Examiner has erroneously cited *In re Van Geuns* for the wrong legal principle.

Regarding the "path profile" recited in claims 12 and 18 of the instant application, Examiner states "the features upon which applicant relies are not recited in the rejected claim(s)." Applicants respectfully disagree. The term "path profile" is a well established term of art in wireless communications. Applicants have furnished U.S. Pat. No. 5,794,128 (front page and col. 9, line 39), U.S. Pat. No. 5,889,768 (front page and col. 3, line 33), U.S. Pat. No. 6,571,082 (front page and col. 12, line 15), and U.S. Pat. No. 6,973,119 (front page and col. 5, line 30) as evidence. All recite "path profile" or "multi-path profile" and have the same specific meaning as previously discussed in the response of August 1, 2006. Thus, applicants respectfully submit that the features upon which they rely are specifically recited in claims 12 and 18. Applicants further submit that Examiner's assertion that "the path profile is understood as any indication as to the communication path between the transmitter and receiver" is clearly erroneous. By way of comparison with *In re Van Geuns*, Van Geuns attempted to add a limitation to claim 42 from the specification. Here,

Examiner attempts to exclude a limitation from claims 12, 18, and all the other pending claims, because it is well-supported by the instant specification.

Regarding Reudink (U.S. Pat. No. 5,648,968) Examiner further states "the patent clearly describes that the delay is controllable by data maintained on the relative strengths which depends on changes in the incoming signals." Applicants understand that Reudink discloses delay control based on "relative strengths." (col. 9, line 1). Reudink does not disclose "providing a distinct delay in the data communication signal in response to the path profile estimate" as required by claim 12 or "providing a distinct delay associated with each antenna and configured to alter the distinct delay in response to a change of a path profile associated with the transmitter channel" as required by claim 18.

Reudink further discloses "[t]he delay time between the transmit signals and its delayed component can be variable depending upon transmission parameters, and controllable by data maintained on the relative signal strengths." (col. 9, lines 6-9). Here, "transmission parameters" refers to transmission parameters of the base station, such as the number of transmit antennas. As previously discussed, Reudink fails to disclose "providing a distinct delay in the data communication signal in response to the path profile estimate" as required by claim 12 or "providing a distinct delay associated with each antenna and configured to alter the distinct delay in response to a change of a path profile associated with the transmitter channel" as required by claim 18. For all the foregoing reasons, applicants respectfully submit that claims 12-14, 17-19, and 22 are patentable under 35 U.S.C. § 102(b). Applicants further submit that claims 1-4, 6-11, 14-16, 20-21, 28-38, and 40-47, having similar limitations, are patentable under 35 U.S.C. § 103(a). Applicants reiterate their previous argument below.

Independent claims 12 and 18 are rejected under 35 U.S.C. § 102(b) as being anticipated by Reudink (U.S. Pat. No. 5,648,968). Claim 12 recites "A communication system comprising: a transmitter having a plurality of spaced apart antennas; **a channel measurement circuit coupled to the plurality of spaced apart antennas and arranged to produce a path profile estimate**

in response to a signal from a remote transmitter; a channel input terminal coupled to receive a data communication signal; and **a delay circuit** operatively coupled between the channel input terminal and the plurality of spaced apart antennas **providing a distinct delay in the data communication signal in response to the path profile estimate.**" Claim 18 recites "A data communication system comprising: a transmitter having a plurality of spaced apart antennas suitable for communication with at least one remote receiver; an element providing a derived version of each communication signal transmitted from a transmitter channel to the plurality of spaced apart antennas; and **a delay element** providing a distinct delay associated with each antenna and configured **to alter the distinct delay in response to a change of a path profile associated with the transmitter channel.**" (emphasis added).

The present invention of claims 12 and 18 is very different from the disclosure Reudink. Examiner has cited control circuit 83 (Figure 8) as an anticipatory disclosure of the foregoing emphasized portions of claims 12 and 18. Applicants respectfully disagree. Reudink does not disclose "providing a distinct delay in the data communication signal in response to the path profile estimate" (claim 12) or "to alter the distinct delay in response to a change of a path profile associated with the transmitter channel" (claim 18). The path profile estimate of claims 12 and 18 is defined at page 12, lines 2-9. Referring to Figure 7, the instant specification teaches "Since use of delay parameters alone to accomplish transmit diversity may not be enough to accommodate reliable signal reception at a mobile terminal under certain unique situations, it is also advantageous to either phase shift the signals to be transmitted and/or scale the amplitude of the signals to be transmitted. These unique situations can be determined by taking channel measurements 730 for the different signal paths 722-728 associated with the multiple antennas 710-714. These channel measurements 730 will provide an indication of the signal phase and signal amplitude to be associated with a particular signal to be transmitted over each signal path 732-736."

Diversity delay of the present invention is described with reference to Figure 3 at page 12, lines 14-20. Therein, the specification teaches "As seen in Figure 3, the base station 102 can

measure the delay profile 302, 304, 306 in the uplink transmission from a mobile terminal 104, 106, 108 to implement one method of choosing channel delays 214-230 associated with multiple antennas 208-212 according to one embodiment of the present invention. The delay 214-230 between the antennas 208-212 can be chosen so that the strongest signal paths between the base station 102 and mobile terminals 104, 106, 108 do not overlap, thereby achieving full diversity. Thus, the present method is distinct from those presently known."

By way of contrast, Reudink does not assign a distinct delay in response to the path profile estimate (claim 12) or in response to a change of a path profile (claim 18). Reudink teaches a relatively constant delay is arbitrarily assigned to each transmit antenna so that the maximum delay is less than 64 μsec. This relation is shown by the equation and corresponding disclosure at column 5, lines 27-40. Reudink specifically teaches that a delay unit is approximated by a formula $DN/2 < 64$ μsec, where D is a unit of delay and N is a number of antenna beams. Reudink fails to disclose that this constant delay is associated with a path profile estimate or a change of a path profile as required by claims 12 and 18.

Reudink discloses at column 8, line 67 through column 9, line 9 "The delay time between the transmit signals and its delayed component can be variable depending upon transmission parameters, and controllable by data maintained on relative signal strengths." Here, applicants understand the transmission parameters to refer to the number of antenna beams N and the 64 μsec maximum delay discussed at column 5, lines 27-40, since these are the only transmission parameters disclosed. Applicants further understand that Reudink teaches using relative signal strength to modify delay time rather than path profile estimates as with the present invention. Thus, for all the foregoing reasons applicants respectfully submit that independent claims 12 and 18 are patentable under 35 U.S.C. § 102(b) over Reudink. Applicants further submit that claims depending from independent claims 12 and 18 are also patentable as depending from patentable claims.

Independent claims 1, 8, 28, 32, 37, 42, and 45 are rejected under 35 U.S.C. § 103(a) as being unpatentable over Rashid-Farrokhi et al. (U.S. Pat. No. 6,400,780) in view of Reudink (U.S. Pat. No. 5,648,968). Examiner admits Rashid-Farrokhi et al. fail to teach altering the distinct delay in response to a change of an estimated path profile and relies on Reudink for this limitation. As previously discussed, Reudink does not disclose at least these limitations of the claimed invention. For example, claim 1 recites "altering the distinct delay associated with a derived version of a data communication signal in response to a change of **an estimated path profile** associated with a channel of the plurality of channels." Claim 8 recites "determining a distinct communication signal delay associated with each communication channel within a plurality of communication channels, wherein each communication channel signal delay is **derived from the estimated path profile** of data associated with the respective uplink signal." Claim 28 recites "the data processor is further directed by the algorithmic software such that it can automatically **determine signal path profile parameters** using algorithmically defined relationships associated with discrete communication signal uplink data such that a signal communicated between the transmitter and each antenna will be characterized by a distinct signal delay." Claim 32 recites "signal deriving means operatively coupled to the signal distributing means for providing communication signal phase parameters associated with communication signals, wherein the phase parameters are determined from channel measurement information associated with the signal distributing means; and variable delaying means operatively coupled to the plurality of spaced apart antennas and the signal distribution means for providing discrete delays associated with **profile path estimates** of the communication signals and the plurality of spaced apart antennas." Claim 37 recites "altering the distinct delay associated with a derived version of the data communication signal and its respective antenna if and when **an estimated path profile** associated with a communication channel changes from a prior estimated path profile." Claims 42 and 45 each recite "a delay element providing a distinct delay associated with each antenna in response to **a path profile estimate** of a signal from the at least one remote receiver." (emphasis added). The foregoing emphasized limitations are not disclosed by Reudink as previously discussed with regard to claims 15 and 18. Thus, applicants respectfully submit that each of independent claims 1, 8, 28,

32, 37, 42, and 45 and their respective depending claims are patentable under 35 U.S.C. § 103(a) over Rashid-Farrokhi et al. in view of Reudink.

In view of the foregoing, applicants respectfully request reconsideration and allowance of claims 1-4, 6-7, 12-22, 37-38, and 40-47. If the Examiner finds any issue that is unresolved, please call applicants' attorney by dialing the telephone number printed below.

Respectfully submitted,

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US005794128A

United States Patent [19]

Brockel et al.

[11] Patent Number: 5,794,128

[45] Date of Patent: Aug. 11, 1998

[54] APPARATUS AND PROCESSES FOR REALISTIC SIMULATION OF WIRELESS INFORMATION TRANSPORT SYSTEMS

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[73] Assignee: The United States of America as represented by the Secretary of the Army, Washington, D.C.

[21] Appl. No.: 530,921

[22] Filed: Sep. 20, 1995

[51] Int. Cl.^{6} H04B 17/00

[52] U.S. Cl. 455/67.1; 455/52.3; 455/65; 364/578

[58] Field of Search .... 455/67.1, 67.3, 455/67.6, 52.3, 65, 63, 67.7; 395/500; 364/578, 514 R, 514 C

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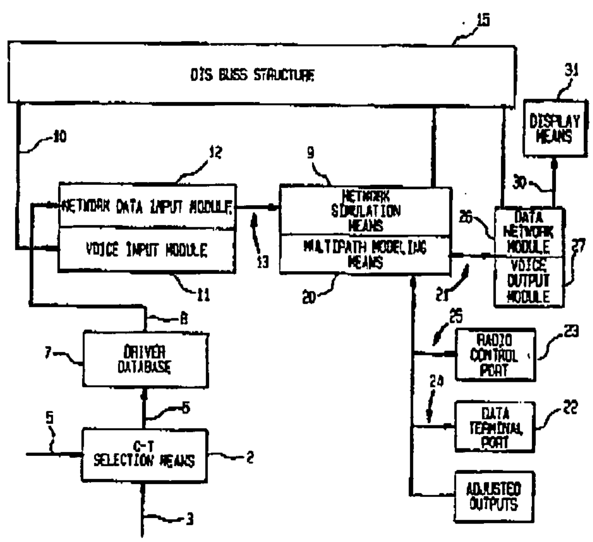
[57] ABSTRACT

Realistic models and processes for simulation of wireless information transport systems are provided which replicate all time and frequency dynamics effects on stationary and mobile communications systems. The preferred embodiment is a realsitic modeling apparatus for simulation of wireless information transport systems comprising a data entry module, a communications traffic selection module, a driver database, and voice and data input modules furnishing a simulation input to a network simulation module. The network simulation module having communications realism effects, a DIS structure, a channel error-burst model to transmit random errors, and a multipath modeling module to integrate deterministic and stochastic effects. The multipath modeling module, having a digital radio model and a Terrain-Integrated Rough Earth Model, influences the simulation inputs forming a multipath output, which is adjusted by voice and data inputs to provide a realistic, real-time simulation output signal to a display module portraying the simulated communications network and link connectivity. The network simulation module, channel error-burst model and multipath modeling module comprise a number of computer programs. A method for realistic simulation of wireless information transport systems in real-time utilizing modeling techniques and computer programs is also disclosed.

32 Claims, 14 Drawing Sheets



characteristics, while FIG. 8 is a graph illustrating the correlation between Frequency Hopping dwells. In both terrain error bursts and the fading process, link fade margins must be calculated by said network simulation means 9. Since it is possible for both the source and the sink to move during communications, the fade margin may need to be calculated more than once (i.e., FadeMargin). The number of calculations depends on the operator's fidelity preference along with the duration of the call or message, the speed that the source or sink is travelling and the fidelity of the terrain database used, represented by the variable MinDistance, which specifies how far a communicator can move without severely changing the path loss value. The number of times that the fade margin must be calculated over the duration of the message or call, L, is determined as follows:

mspeed=MAX[source.Speed, sink.Speed]; represented in m/s

$$L = ROUNDUP\left[\frac{mspeed \cdot \left(\frac{msg.OverallSize}{data.rate}\right)}{MinDistance}\right]$$

The ROUNDUP[ ] function returns a value of L as an integer. The fade margin is determined from a plurality of user specified receiver performance thresholds, based on the higher value of either an ambient noise floor or system sensitivity, and a calculated receiver RMS received power level, which is based on dynamic path loss and both user-specified transmission power and antenna gains. Fade margin is calculated as:

FadeMargin=RxInput−RxThreshold; N=1 to L

where

RxInput=TxPower+TxAntGain+RxAntGain−TiremLoss

RxThreshold=MAX[ThermalNoise, sink.NoiseFloor]

ThermalNoise=−174+10 $\log_{10}$ [Bandwidth];

and TxPower, TxAntGain, RxAntGain, sink.NoiseFloor and Bandwidth are among a plurality of user-specified radio parameters. To compute TiremLoss, a path profile must be generated between the source and the sink and said TIREM software program exercised.

In order to determine the impact of terrain on the call or message, a plurality of terrain error bursts, ("terrain_EB") are generated whenever said fade margin dips below 0 dB. Those positions of said plurality of terrain error bursts relevant to the beginning of the call or message are stored in structure:

$$TEBi;\ \text{where } i = 1 \text{ through } \frac{\text{number of bursts}}{2}$$

for subsequent countermeasure processing and overall determination of whether the communications were successfully received. Thus for each FadeMargin (1 to L):

If FadeMargin≦0 & terrain_EBflag not set,

note start of terrain_EB:

TEBi=BITPOSITION[SegmentN]=

$$N \cdot \left[\frac{MinDistance}{mspeed}\right] \cdot TransRate + TEBi$$

where TransRate is a among a plurality of user-specified radio parameters, and BITPOSITION[ ] is a function that returns the bit number in relation to a passed value.

terrain_EBflag=start.

If FadeMargin>0 & terrain_EBflag=start, note end of terrain_EB:

$$TEBi = \left[\frac{MinDistance}{mspeed}\right] \cdot TransRate + TEB(i-1)$$

terrain_EBflag=end.

A plurality of error-burst generators of said network simulation means 9 determine the presence, or arrival, and duration of a deep fade, which is a fade below said performance threshold, during the simulation using a plurality of exponential distributions with a mean as a function of frequency, relative velocity and fade margin. Said Received Signal Strength ("RSS") for a channel in a multipath environment is described by Rayleigh fading amplitude statistics. This fading increases bit errors caused by poor Signal-to-Noise Ratio ("SNR"). The Rayleigh fading process has been characterized for fixed and frequency-hopping (FH) signals and generic models have been developed for determining the fade depth as functions of a plurality of correlation coefficients that could be validated.

Relative velocity, v, of the source with respect to the sink is needed to calculate the fading effects. This is computed using a plurality of user-specified vehicle parameters, breaking each vehicle speed into x and y axis movements. Fading events are modeled as a function of rate and duration. The average fade rate is calculated as:

$$n(r) = \frac{\sqrt{2\pi}}{\lambda}\, vre^{-r^2}$$

and the average fade duration is calculated as:

$$t(r) = \frac{\lambda(e^{r^2}-1)}{\sqrt{2\pi} \cdot vr} = \frac{1-e^{-r^2}}{n(r)}$$

where r is the fade depth, v is the vehicle velocity and λ is the wavelength derived from the radio frequency. Fade depth, r, is derived from the dB fade margin as:

$$r = 10^{\frac{-FadeMargin}{20}}$$

and is expressed as voltage normalized to RMS. Modeling of the fading process for fixed frequency and frequency-hopping transmissions is discussed further below.

To determine the impact of multipath fading on the call or message, a plurality of fading error bursts, fade_EB, are generated based on the average fade rate and average fade duration. Those positions of these bursts relevant to the beginning of the call or message are stored, so that:

$$FEBi;\ i = 1 \text{ through } \frac{\text{number of bursts}}{2}$$

for subsequent countermeasure processing and overall determination of whether the communications was successfully received. An initial fade_EB is first calculated by determining the time to the next fade_EB, adding it to the current time to get an end_of_fade_EB time, calculating the duration of the fade_EB, and subtracting it from end_of_fade_EB to get the start time of fade_EB, as follows:

calculate n(r) using Fademargin1

time_to_next_fade_EB=EXPONENTIALLY-DISTRIBUTE[1/n(r)] where EXPONENTIALLY-DISTRIBUTE[ ] is a function that returns an exponentially-distributed random variable with mean of the passed value, so that

US005889768A

United States Patent [19]

Storm et al.

[11] Patent Number: 5,889,768

[45] Date of Patent: Mar. 30, 1999

[54] METHOD OF AND APPARATUS FOR PILOT CHANNEL ACQUISITION

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[73] Assignee: Motorola, Inc., Schaumburg, Ill.

[21] Appl. No.: 706,150

[22] Filed: Aug. 30, 1996

[51] Int. Cl.[6] H04B 7/216

[52] U.S. Cl. 370/320; 370/209; 370/331; 370/332; 375/200; 375/206; 455/436; 455/438

[58] Field of Search 370/209, 331, 370/332, 335, 347, 320; 375/200, 206, 362, 364; 455/436, 437, 438, 442

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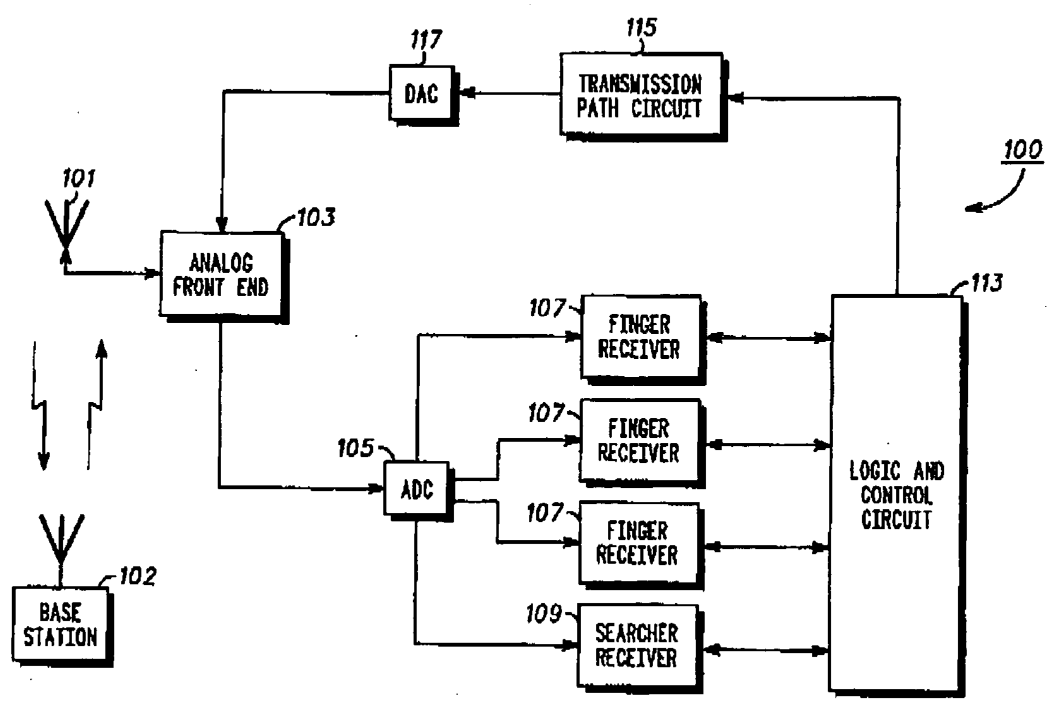
[57] ABSTRACT

A wireless communication device 100 acquires a pilot channel before an assigned slot when the wireless communication device is operating in the slotted mode of a CDMA system. The wireless communication device comprises a searcher receiver 107 that determines the short-term average pilot strength of active and neighbor pilot channels. Finger receivers 107 determine the long-term average pilot strength of the active and neighbor pilot channels. A logic and control circuit 113 assigns the finger receivers to the pilot channels according to their short-term average pilot strength, determines if the long-term average pilot strength of a neighbor channel is greater than the active pilot channel's pilot strength, and determines to hand off to the neighbor pilot channel with the greater long-term average pilot strength. Moreover, an early detection correlation length can be dynamically adjusted according to the pilot strength of the active pilot channel to shorten the pilot acquisition process.

21 Claims, 5 Drawing Sheets



When radiotelephone 100 is awake, antenna 101 receives from the active pilot a neighbor set, which is a list of pilot channels of base stations that are probable candidates for handoff. A record of the active pilot and the neighbor pilots are stored in logic and control circuit 113 before radiotelephone 100 goes to sleep.

Searcher receiver 109 is capable of sweeping the pilot channel signal of the active pilot and neighbor pilots to determine the pilot channel strength of each. Searcher receiver 109 determines pilot channel strength by a complex correlation process which provides a measure of E_c/I_o in decibels (dB), where E_c is a measure of the pilot energy and I_o is the total power spectral density in the received bandwidth. This power measurement will be referred to as short-term average E_c/I_o and represents a signal-to-signal plus noise ratio.

A pilot signal emanating from a base station may travel along several paths called "rays," thus producing multi-path signals. In performing a sweep of the pilot signal of the neighbor pilots, searcher receiver 109 sets a multiple chip window centered on the code phase offset of the particular pilot signal. The purpose of the sweep of the chip window is to develop a multi-path profile of the pilot signal. A complex correlation and measure of short-term average E_c/I_o is obtained for each of the multiple chip offsets of the chip window in searching for the strongest ray of the neighbor pilot that appears in the chip window.

The complex correlation has two stages. In an early detection stage, short-term average E_c/I_o is determined for a subset of the maximum number of chips (the "chips" referenced here are of the pilot signal) normally correlated to provide an indication of whether sufficient pilot signal energy exists at the particular chip offset. The subset of the maximum number of chips is referred to as an early detection correlation length. When the short-term average E_c/I_o is great enough at the early detection correlation length, the second stage is performed, which is to complete the correlation for the maximum number of chips.

The method of use and operation of the wireless communication device as constructed and described above will now be described with reference to FIGS. 2–5, which are flow charts illustrating a method of sweeping a pilot channel, a method of pilot channel acquisition carried out by the wireless communication device, and a method of assigning a finger receiver to a pilot channel, respectively.

Reference will now be made to FIG. 2, which illustrates a method 200 of sweeping a pilot channel. Initially, logic and control circuit 113 determines whether there are any neighbor pilots in the neighbor set. (See step 317 of FIG. 3.) If so, searcher receiver 109 begins a sweep of the neighbor pilots. (Step 201.) In order to end the method for a sweep of a particular neighbor pilot, logic and control circuit 113 determines whether all chip offsets of the particular neighbor pilot have been correlated. (Step 203.) If so, the sweep of the neighbor pilot is completed. (Step 215.) If not, searcher receiver 109 performs the correlation at a particular chip offset. (Step 205.) As part of the correlation, searcher receiver 109 determines the short-term average E_c/I_o of the particular chip offset at the early detection correlation length. (Step 207.)

Logic and control circuit 113 determines whether the pilot signal strength at the early detection correlation length is less than an early detection threshold (EDT). (Step 209.) When, after the correlation of the subset of maximum chips, the short-term average E_c/I_o is less than the EDT, it is likely that the pilot signal is not present at that particular chip offset, thus the correlation at the particular chip offset is terminated, (step 213), and logic and control circuit 113 again determines whether all chip offsets of the particular neighbor pilot have been correlated.

When, after the correlation of the subset of maximum chips, the short-term average E_c/I_o is not less than the EDT, indicating that there is sufficient energy in the pilot signal at the particular phase offset, the correlation is continued through the maximum number of chips, (step 211), and control of the method is returned to step 203. Eventually, all of the chip offsets for a particular neighbor will be correlated (either partially of fully). The short-term average E_c/I_o for the strongest ray will be provided and used in determining whether a finger should be assigned to the strongest ray of the swept neighbor pilot signal.

Furthermore, the chip offset representing the strongest ray is used by the assigned finger receiver to track the neighbor pilot. A purpose of tracking the neighbor pilot is to ascertain the presence or absence the neighbor pilot over time as the searcher pilot continues to sweep the neighbor pilots of the neighbor set. Another purpose is to provide the pilot strength of the tracked neighbor pilot.

Depending on the number of finger receivers provided in radiotelephone 100, multiple fingers can be assigned to multiple rays of the same neighbor pilot to obtain a pilot signal strength representative of the combined rays.

Method 200 is performed for all of the neighbor pilots of the neighbor set, provided radiotelephone 100 wakes up early enough to complete the sweep of each neighbor before the paging channel is to be monitored at the assigned slot. For example, there may be 20 neighbor pilots in the neighbor set, and a 60-chip window for each neighbor pilot. Accordingly, 1200 correlations should be performed. One can appreciate the importance of terminating the correlation for a particular chip offset at the early detection correlation length to reduce the time that radiotelephone 100 must wake up before monitoring the paging channel to search for and acquire the pilot channel having the greatest strength.

The values for the full correlation length, the early detection correlation length, and the EDT are chosen to provide satisfactory searcher speed while achieving acceptable probability of missing a pilot signal and acceptable probability of falsing.

According to the invention, the EDT is dynamically adjustable depending upon the strength of the active pilot signal, which is an important aspect of the invention. The EDT can be re-set from a first value to a second value. "Dynamic" as referred to herein means the ability to make an adjustment to a pre-programmed parameter after the pilot acquisition method has commenced. When there is a sufficiently strong pilot signal, the importance of finding a stronger neighbor pilot signal is diminished, thus allowing a higher acceptable probability of missing weaker pilots while maintaining a high probability of detecting still stronger pilots. This means that the EDT can be raised, resulting in a faster sweep of each neighbor pilot and reducing the total time needed to sweep the entire neighbor set.

FIGS. 3 and 4 are flow charts illustrating a method 300 of pilot channel acquisition carried out by the wireless communication device. As previously described, in the preferred embodiment, the EDT is initially set at a first value. (Step 301.) Upon waking up, searcher receiver 109 sweeps the active pilot to find the strongest ray, (step 303) and determines the active pilot's short-term average E_c/I_o, (step 305), in a similar manner as described for sweeping a neighbor pilot. Logic and control circuit 113 then determines whether

US006571082B1

(12) **United States Patent**
Rahman et al.

(10) **Patent No.: US 6,571,082 B1**
(45) **Date of Patent: May 27, 2003**

(54) **WIRELESS FIELD TEST SIMULATOR**

(75) Inventors: **Iftekhar Rahman**, Billerica, MA (US); **Nabil Hinnawi**, Boxborough, MA (US)

(73) Assignee: **Verizon Laboratories Inc.**, Waltham, MA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **09/430,105**

(22) Filed: **Oct. 29, 1999**

(51) **Int. Cl.**[7] **H04B 17/00**
(52) **U.S. Cl.** 455/67.1; 455/456; 455/67.4; 455/67.6; 342/451; 342/452
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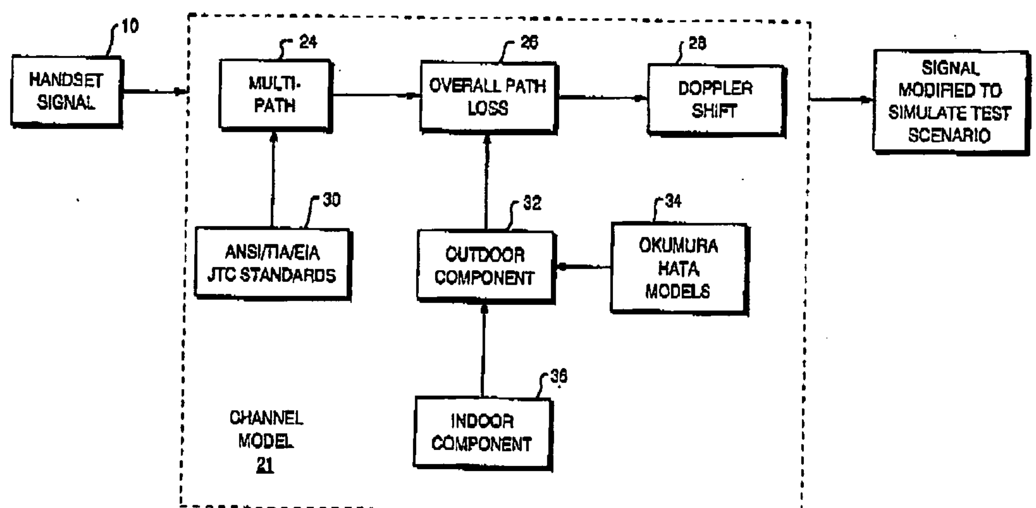
(57) **ABSTRACT**

A method and system for testing network-based location determination technologies within a single test area in the field. Channel models are developed to simulate the propagation impairment conditions associated with identified test scenarios. The channel models for an identified test scenario can be developed by estimating the amount of multi-path, path loss, and Doppler frequency shift effects one would expect under the conditions and environment of the identified tests scenario. The path loss effects of an identified scenario may be estimated by combining the Okumura-Hata outdoor path loss models with available indoor path loss models. A single test area having receiving antennas and signal transmission of fixed and known geographic locations may be selected. A network-based location determination technology can be comprehensively tested at the single test location, under propagation impairment conditions not naturally occurring there, by modifying the system's signals according to the channel models developed to simulate the propagation impairment conditions of identified test scenarios. Similarly, cellular, personal communication systems (PCS), and broadband wireless communications system may also be tested for the quality of the voice and data transmissions at a single test location.

34 Claims, 17 Drawing Sheets



channel model 21 should be considered is when a test scenario assumes a cellular call is being placed from a moving car. For test scenarios that assume the source of the signal transmission, e.g., the handset, is in motion, the Doppler shift 28 component of the channel model 21 may be determined by the following formula:

$$f_d = V_m fc/c \qquad \text{Formula 8}$$

Where

V_m is the velocity of the mobile terminal or cellular handset

c is the velocity of light

fc is the frequency of the signal emitted by the mobile terminal

f_d is the shift in the frequency fc

By considering and developing the multi-path 24, overall path loss 26, and Doppler shift 28 components of the channel model 21 corresponding to an identified test scenario, the propagation impairment conditions of that test scenario can be simulated in the field. The channel model 21, developed for an identified test scenario, determines how the parameters of a signal may be modified to simulate the impairment conditions of the identified test scenario.

Referring to FIGS. 5A–5F, some of the ANSI/TIA/EIA JTC for PCS (hereafter referred to as the JTC) multi-path models are shown. The JTC multi-path models 30 may be used to develop the multi-path 21 (of FIG. 4) component of a channel model 21 (of FIG. 4) for an identified tests scenario. The JTC multi-path models 30 are defined by nine (9) propagation environment groups. The propagation environment groups identified are as follows: Indoor residential; Indoor office area; Indoor commercial area; Outdoor urban high-rise area with low antenna; Outdoor urban low-rise area with low antenna; Outdoor residential area with low antenna; Outdoor urban high rise area with high antenna; Outdoor urban/suburban low-rise area with high antenna; and, Outdoor residential area with high antenna. FIGS. 5A–5F includes tables representing six of these groups, as indicated on each table of FIG. 5. For each of these groups, the corresponding table expresses the values of the signal parameters, e.g., relative time delay, relative amplitude (relative power) and number of paths corresponding to three different profiles, namely, A, B and C (note that the JTC refers to the different profiles as "channels").

The three profiles represent three different multi-path models each with an associated probability of occurrence for the same propagation environment group. Thus, for the indoor office environment FIG. 5A, for example, the probabilities of occurrence of Profiles A, B, and C are 0.50, 0.45., and 0.05, respectively. Note that the probabilities of occurrences are not shown in the tables of FIG. 5. Generally speaking, Profiles A and B each have a probability of occurrence close to ½, while Profile C has a 0.05 probability of occurrence.

Several profiles or models are used due to the fact that each of the propagation environments are so broadly defined that it would be inaccurate to represent them with just a single profile. Alternatively, a large number of profiles may be undesirable for the reason that they may be difficult to manage. A suitable compromise, for example, are the three profiles described above with associated probabilities of occurrence.

A multi-path model may be expressed as consisting of several individual signals where each individual signal travels a different path in arriving at the same receiver. Each row of a table within the JTC multi-path models 30 represents an

individual signal within the particular multi-path model. For example, consider FIG. 5A which includes information describing three multi-path environment models, respectively, specified as Profiles A, B, and C (or Channels A, B, and C). Profile A describes a first of these multi-path model as including three individual signals as specified by entries in rows 1–3 of FIG. 5A. Likewise, Profile B (or Channel B) of that table has entries in rows one through six, indicating that six individual signals comprise that "multi-path" model.

The entries in the first column of each profile (i.e., columns 1, 3, and 5) represent the relative time delay, in nanoseconds, of each individual received signal of the received multi-path signal. The first signal of row 1 for each multi-path profile is treated as the time baseline in regard to the relative time delays of the subsequent signals. The entries in the second column of each profile (i.e., columns 2, 4, and 6) represent the relative average power, in dB (decibels), of the individual received signals of the multi-path signal. Again, the first signal corresponding to row 1 for each-multi-path profile is treated as the power baseline regarding the relative powers of the subsequent signals.

Using FIG. 5A (indoor office area environment) as an example, Profile A (Channel A) shown in columns 1 and 2 can be used to represent a test scenario multi-path model including three individual signals (high probability of occurrence), as can be seen by the entries in rows 1–3 of those columns. The first signal (row 1) is assumed to arrive at a receiving antenna at time zero, shown in row 1, column 1, with a second signal (row 2) of the multi-path model arriving 50 nanoseconds after the first (row 2, column 1) and a third signal arriving 100 nanoseconds after the first (row 3, column 1). Referring to column 2 now, the average power of these three signals are 0 dB (row 1, column 2), −3.6 dB (row 2, column 2), and −7.2 dB (row 3, column 2) for first signal, second signal, and third signal, respectively.

As previously described above, each of the propagation environments are so broadly defined that several different test scenarios may be represented by the same propagation environments defined in FIGS. 5A–5F. By using different profiles, different multi-path models for different scenarios may correspond to the same propagation environment. It should be noted that if there are more than three test scenarios per propagation environment, some of the scenarios may be represented by the same multi-path profile. As generally known to those skilled in the art, this is a limitation of the JTC, and other models.

To select a particular model, some evaluation may be performed. For example, by examining the environment which defines the scenarios in a particular group, a qualitative best fit of the scenarios to profiles may be performed. As known to those skilled in the art, this includes an understanding of the environment, for example, as to how a signal is propagated from a transmitter to a receiver in a particular environment. For example, consider two urban class scenarios, a first at the intersection of streets and a second occurring mid-block. At an intersection, signals may be arriving at a point via more paths since signals may be coming down a street as well as deflecting off middle and corners of buildings. At mid-block, it may be expected that fewer signals are deflecting off the immediate vicinity of a building.

To comprehensively test a network-based LDT, a test plan containing a wide range of test scenarios covering the possible operational conditions and environments should be developed. For example, nine environmental groups as identified by the JTC may serve as an initial starting point

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(54) **METHOD AND APPARATUS FOR RECOGNIZING A RECEIVING PATH IN A CDMA SYSTEM**

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(58) **Field of Search** 375/147, 343, 375/357, 363, 371

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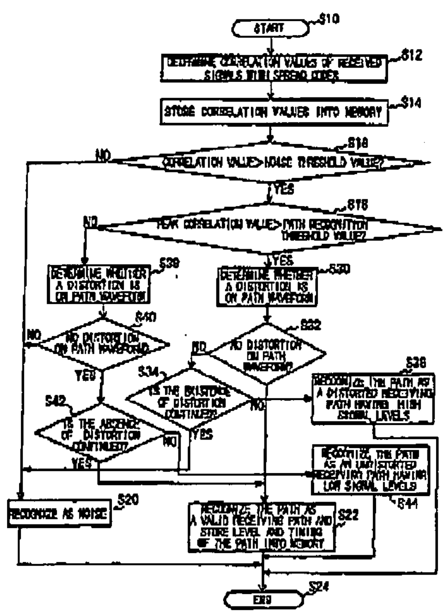
(57) **ABSTRACT**

A method and system are provided for recognizing a path having low level signals, which is conventionally treated as useless, as a valid receiving path. Recognition is made from a plurality of receiving paths in a CDMA wireless telecommunication system by receiving at least one set of signals through a transmission path, generating at least two spread codes each with its own delay time, and calculating at least two correlation values of the set of signals with the spread codes. A CDMA wireless telecommunication mobile station is also provided for receiving a set of telecommunication signals through a telecommunication path from a base station. At least two spread codes are generated, each with its own delay time and a predetermined number of spread code bits. At least two correlation values of the set of signals are calculated with the spread codes.

26 Claims, 12 Drawing Sheets



transmission signals the processing of error correction encoding, frame encoding, data modulation and spread modulation, and then sends the processed signals to the RF signal processor 56. The base band signal processor 58 performs on the received signals sent from the RF signal processor 56 the processing of reverse spreading, chip synchronizing, error correction decoding, data multi-separation, maximum ratio composition of inter-sector diversity handover, etc. The controller 60 has control functions such as sending and receiving control signals to perform RF link establishment, RF link management, etc. The wired communication interface unit 62 facilitates an interface among the BTS, MCC-SIM (not shown) of the base station 50 and the base station control unit 70 (see FIG. 3).

FIG. 6 is a schematic block diagram showing an embodiment of the base band signal processor 40 of the mobile station 30 according to the present invention. According to this embodiment, the base band signal processor 40 includes a spread code generator 12, a correlator 14, a memory 16, a comparator 18, registers 20 and 22, a waveform distortion detector 80 and a path recognizing unit 82. The register 20 stores a predetermined path recognition threshold value, and the register 22 stores a predetermined noise threshold value.

The spread code generator 12 generates a plurality of phase-shifted spread codes each of which is comprised of a predetermined number of spread code bits, and provides the generated codes to the correlator 14. The correlator 14 includes, for example a matched filter and a sliding correlator, and acquires correlation values by determining correlations of received signals with the spread codes. The correlator 14 acquires a correlation profile (a multi-path profile), such as a delay profile, based on the correlation values. The memory 16 stores the plurality of correlation values acquired by the correlator 14. The comparator 18 determines whether a set of received signal is noise or not by comparing the correlation values with the noise threshold value. The comparator 18 also compares a peak correlation value of the path with the path recognition threshold value. A path of which the peak correlation value is larger than the path recognition threshold value is recognized as a candidate for a valid receiving path for demodulating received signals through the path, and the location of the peak correlation value is stored as a path location for the receiving path in the memory 16.

The waveform distortion detector 80 determines whether there is a distortion on a path waveform of a particular receiving path, where the path waveform is represented as a correlation profile, such as an impulse response or a delay profile. Otherwise, the waveform distortion detector 80 may detect a distortion on a path waveform based on a frequency transfer function or frequency characteristics, which can be acquired by performing Fourier Transformation on the path waveform represented as a noise response or a delay profile.

It is quite frequent that the path waveform of a receiving path represented as a correlation profile, such as a delay profile, is distorted by the effects of the multi-path fading, interferences between signals, noises, etc. For example, since levels of received signals are generally low in the area having weak field strengths, the peak correlation value of the received signals can be smaller than the path recognition threshold value even though the receiving path through which the signals are transmitted was actually valid for demodulation. According to the present embodiment of the present invention, the waveform distortion detector 80 determines whether a path waveform of a correlation profile is distorted or not based on at least two correlation values. The path recognizing unit 82 recognizes at least one receiving path as a valid receiving path among a plurality of receiving paths through which signals are transmitted based on the comparison result of the comparator 18 and the determination result of the waveform distortion detector 80. The memory 16 stores the levels and a delay timing of the valid receiving path.

FIGS. 7(*a*) and 7(*b*) show diagrams of path waveforms of receiving paths represented by impulse responses or delay profiles. FIG. 7(*a*) shows an example of a path waveform to which no distortion has occurred. As shown, this undistorted path waveform is sharp and symmetrically wedge-shaped and centered by the point p(N).

FIG. 7(*b*) shows an example of a path waveform to which a distortion has occurred. As shown, this distorted path waveform is of an unsymmetrical and relatively slowly sloped wedge compared to that shown in FIG. 7(*a*). This slow slope of the path waveform is due to the effect of interferences or noises. The waveform distortion detector 80 detects the existence of the distortion by, for example, calculating slopes among correlation points.

FIGS. 8(*a*) and 8(*b*) show graphs of frequency transfer functions or frequency characteristics acquired by performing Fourier Transformation on correlation profile waveforms, such as delay profile waveforms. FIG. 8(*a*) shows a frequency characteristic of an undistorted path waveform. As shown, in case distortion has not occurred, the frequency spectrum has a shape of plane table.

FIG. 8(*b*) shows a frequency characteristic of a distorted path waveform. Compared to FIG. 8(*a*), this frequency characteristic has a very steep valley. This valley is also due to the effect of interferences or noises. The waveform distortion detector 80 may also detect the existence of distortion on the correlation profile waveform by, for example, calculating slopes between sample points of the frequency characteristic.

FIG. 9 is a block diagram of an embodiment of the waveform distortion detector 80 of the present invention. The waveform distortion detector 80 includes registers 84, 86 and 88, selectors 90, 92 and 94 and a comparator 96. The waveform distortion detector 80 of the present embodiment determines whether there is any distortion on a path waveform of a correlation profile by evaluating slopes of the waveform.

Again referring to FIG. 7, a correlation value at a specific delay time is expressed as p(k) in a correlation profile. At two points a and b, where b>a, a slope between the two points a and b is given by;

$$(\text{slope between points } a \text{ and } b)=[p(b)-p(a)]/(b-a) \quad (1)$$

Here, let β be the ratio of p(b) to p(a). That is,

$$p(b)=p(a)\times\beta \quad (2)$$

where p(b)>p(a).

By using equations (1) and (2), we can get

$$(b-a)\times(\text{slope between points } a \text{ and } b)=(\beta-1)\times p(a) \quad (3)$$

More detailed description of the distortion detecting operation of the waveform distortion detector 80 of the present invention is given hereinafter using the above equations.

As mentioned before, according to the present invention, in order to recognize a receiving path as a valid path for demodulating received signals, the shape of the path waveform represented as a correlation profile, such as impulse response or delay profile, is made, and if the shape of the path waveform is not as sharp as that of an undistorted path waveform, it is determined that a distortion is present. As for